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CHALLENGES IN TREATING CANADIAN SPECIES

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1. Introduction

Wood is a porous material comprised of long narrow hollow cells that are connected by apertures: pit structures in both softwoods and hardwoods and perforation plates in vessels of hardwoods that allow movement of sap from the tree roots to the foliage and movement of nutrients and photosynthesis products from cell to cell in the living tree. For typical Canadian softwood species, wood is two-thirds or more void space. Thus, in principle, penetration of preservative into wood should be easy, especially in the parallel to grain (longitudinal) direction. However, in general, it is a challenge to consistently treat Canadian wood species to CSA specifications because of their anatomical characteristics.

In ***softwoods***, the tree's fluid transport and structural functions are both provided by tracheids. The main flow paths are through overlapping longitudinal tracheids which are connected by "bordered pits" primarily along the radial walls. This facilitates penetration along the grain and in the tangential direction (around the annual rings). Another important flow path is through ray cells in the radial direction which are connected by different types of pits to one another and to adjacent tracheids. However, during heartwood formation in the tree, and during drying of the sapwood after the tree is cut, these pits close or "aspirate", making the wood much less permeable. This is a natural defense function of the tree against desiccation by wounding. The closure is achieved by movement of a mobile plug to block the aperture. In sapwood, the pits may not seal completely and usually there are still sufficient openings to allow penetration of liquids under pressure. However, even the sapwood of some softwood species such as spruces and interior (inter-mountain) Douglas-fir is difficult to penetrate. In heartwood, pit aspiration is accompanied by deposition of resins and other materials on the pit openings (encrustation) that effectively seals the pits. As a result, most heartwood is highly refractory and preservative penetration is limited to the sapwood of most softwood species unless a pretreatment such as incising is used to improve the transverse penetration. A common misconception is that less dense woods, which have higher relative void volumes, are easier to penetrate. Because permeability is softwoods depends on the closure of bordered pits, density is not a factor. In fact, within a tree, the denser latewood or summer wood is often better penetrated because the degree of pit aspiration is lower. Another major pathway in softwoods is longitudinal and radial resin canals, where present (An et al 1998). These are not connected to tracheids but are lined with soft walled cells that allow preservative to pass through.

In ***hardwoods***, the tree's transport functions are provided by larger diameter vessels and the structural functions are provided by smaller diameter fibres, similar to tracheids. The major flow paths are through longitudinal vessels, which are large and mainly unobstructed in sapwood. They are readily penetrated during pressure treatment and most of the preservative flow is along the grain. However, liquid penetration also can occur transversely, mainly through pit structures that connect the different cell types in the tangential direction, and radially through ray structures. Thus, hardwood sapwood tends to be more permeable than softwoods. However, because the vessels are relatively far apart, preservative components may not always be well distributed to all the fibres. Heartwood permeability is much more variable than for softwoods. Unless the vessels become occluded with tyloses, blockages created during heartwood formation or wounding of the tree, they may remain open to treatment and penetration may be as easy as in sapwood. Basswood (*Tilia* species), red oak and some poplar species are examples of easily treated hardwoods. White oak is an example of a hardwood species that always has refractory heartwood because of tyloses and many other hardwoods develop them as a response to insect attack or other wounding.

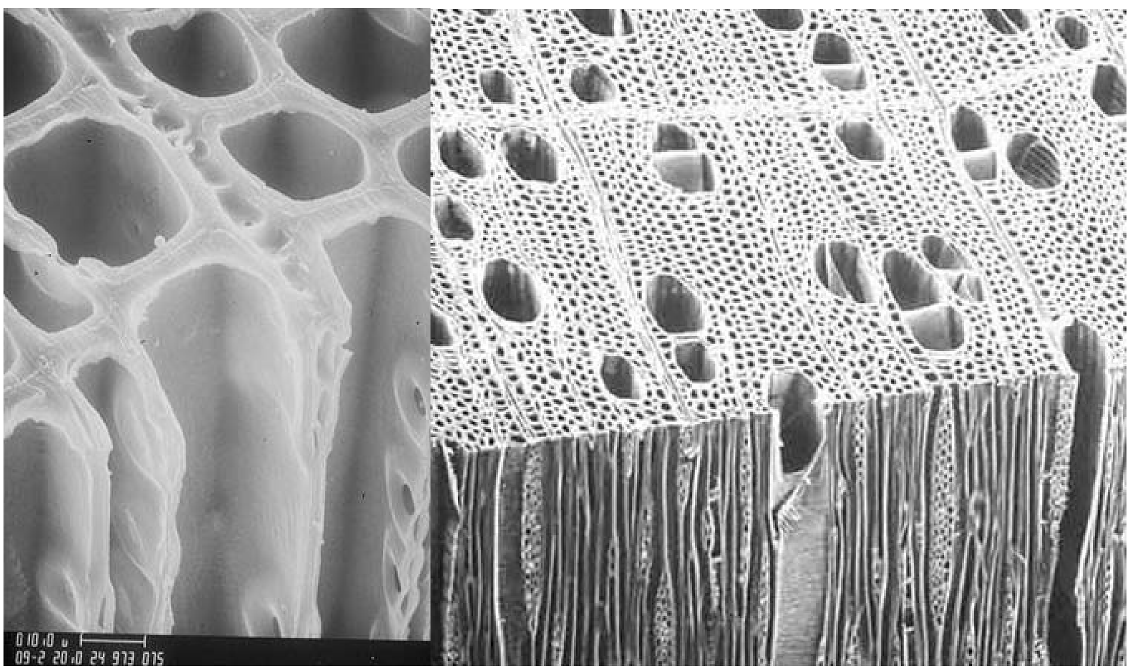


Figure 1: Typical structure of a softwood (pine) and hardwood (birch) (SWST Slide set on Wood structure) Note the pine is much more highly magnified than the birch

Preservative treatment of lumber of Canadian softwood species is challenging because most have thin sapwood and extremely refractory heartwood making it difficult to achieve specified penetration and retention levels without extraordinary effort. This contrasts with the USA where the thick sapwood and permeable southern pine species predominate and Western Europe where relatively permeable Scots pine is available and Australasia where Radiata pine and Slash pine (a southern pine) are available.

There are thick sapwood species in Canada such as ponderosa pine (*Pinus ponderosa Laws.*) and red pine (*P. resinosa* Ait.), but the volumes available for treatment are low compared to the amounts of wood treated annually in Canada. The pine volume shown in Table 1 is mainly thin sapwood jack pine (*P. banksiana Lamb.*) and lodgepole pine (*P. contorta* var *latifolia* Dougl.). The thick sapwood species are often used for poles, square posts and timbers (red pine) and treated joinery products (ponderosa pine) where good levels of treatment are important. Some Canadian softwood species have reasonably good heartwood penetration, especially if properly incised. Western Hemlock *Tsuga heterophylla* [Raf] Sarg.), Pacific silver fir (*Abies amabilis* [Dougl.] Forbes) and alpine fir (*Abies lasiocarpa* [Hook] Nutt.) are examples of this. Indeed, incised Pacific silver fir is one of the few species that can readily be treated to meet US and Candian standards requiring 10mm penetration, and if separated from the Hem-fir mix, would be an excellent species for treated applications as noted by Bramhall and Cooper (1972) and Morris (1995). Species with moderate sapwood levels such as jack pine, lodgepole pine and coastal Douglas-fir (Pseudotsuga menziesii [Mirb] Franco) are acceptable for round products such as posts, poles and piling, but after they are processed into lumber, most boards expose a great deal of heartwood. These species are somewhat more refractory but may also be treated adequately with effective incising. The more abundant species such as spruce and larch species, and balsam fir (*Abies balsamea* [L.] Mill) are generally very difficult to treat.

While hardwood species are generally easier to treat, their availability is limited and they are not used extensively for treated wood products in Canada.

Table 1: Volumes of Canadian species groups (Lowe et al. 1996)

Coniferous		Broadleaved	
Spruce	8534	Poplar - aspen	3670
Pine	4808	Birch	1242
Fir	3087	Maple	724
Hemlock	1775	Other	305
Douglas-fir	881	Total - Broadleaved	5941
Larch	185		
Cedar and other	947	All species	
Total - Coniferous	20218	Total - All species	26159

Characteristics of Canadian species

Different Canadian species vary in their quality of treatment and performance of treated wood in service, depending on relative sapwood thickness (e.g. Figure 2), sapwood and heartwood treatability and heartwood natural durability. A comparison of these properties is shown in Table 2 which arranges species in a hierarchy of expected performance of Canadian softwood species following preservative treatment. The natural durability depends on the extractive content and to a lesser extent on the wood susceptibility to moisture absorption. For example, western red cedar (*Thuja plicata* Donn), yellow cypress (*Chamaecyparis nootkatensis* [D.Don] Spach), eastern white cedar (*Thuja occidentalis* L.) and black locust (*Robinia pseudoacacia* L.) have relatively high concentrations of extractives that are repellent or toxic to insects and fungi. Other species such as Douglas-fir, white pine (*Pinus strobus* L.) and oak have moderate levels of less effective extractives and have some moderate resistance to deterioration. Other species have an undeserved reputation for high natural durability (examples are larch/tamarack and hemlock) and untreated wood of these species should not be relied on for uses with moderate to high decay hazard.

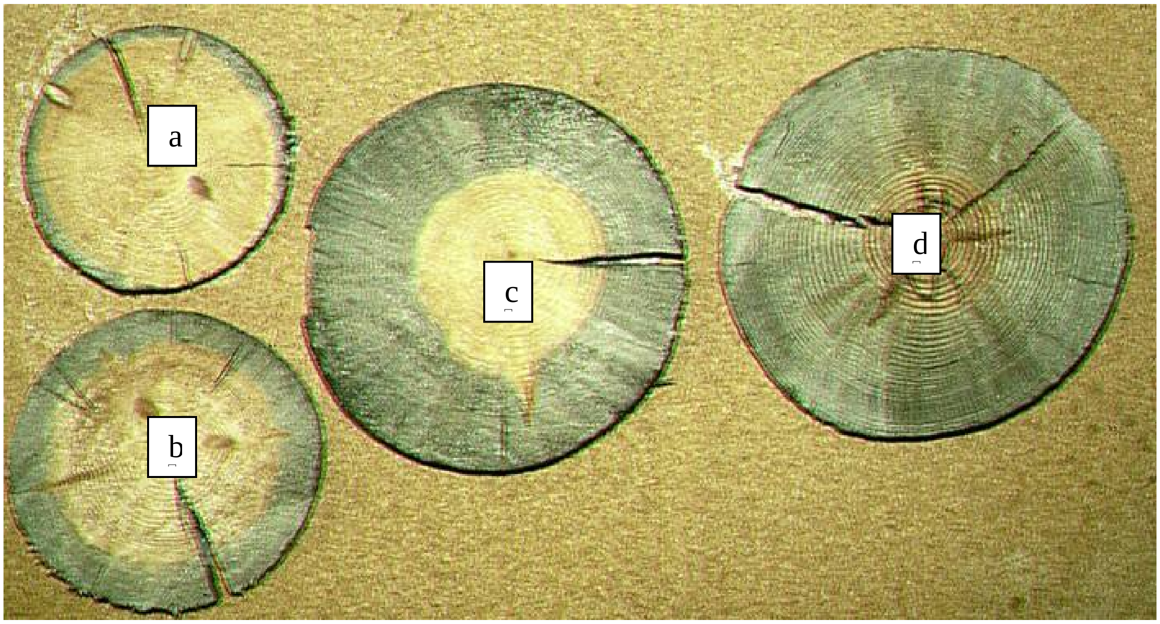


Figure 2: Examples of species effects on pole sapwood thickness and preservative penetration – mpine species treated with CCA a) red pine top, b) jack pine butt, c) red pine, d) southern pine.

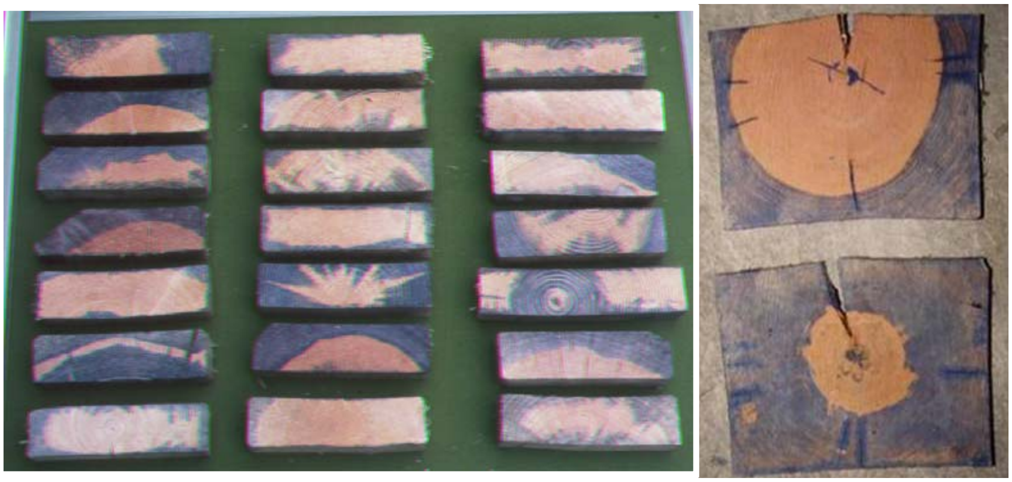
Oak, hard maple and beech are treated with creosote for railway ties and hardwoods including these species and birch are treated with water based preservatives for guiderail post in some provinces. A significant amount of aspen poplar (*Populus tremuloides* Michx) is treated for landscaping uses, although this material is mainly heartwood and generally is not well protected by such treatment. Treatment of these species with CCA introduces particular concerns as in some cases (e.g., aspen), very high levels of treatment are required for efficacy and others such as maple, beech and oak demonstrate excessive arsenic leaching when exposed to weathering (Stevanovic-Janesic et al. 2001). Their performance with newer copper amine based preservatives has not been evaluated.

There is considerable variation in the treatability of wood within a species (e.g., Figure 3). A notable example of this is the effect of geographic location and related climatic conditions where the trees were grown. The most notable example of this is the extremely refractory nature of inter-mountain Douglas-fir compared to the coastal grown trees. This geo-climatic effect has also been documented for western hemlock (Cooper and Ross 1977) and is likely a factor for other species as well.

When faced with treating refractory wood species, there are a number of approaches that can be taken to improve preservative penetration and retention as reviewed by Morrell and Morris (2002) and discussed below.

Table 2: Hierarchy of Canadian softwood species based on their relative sapwood content, preservative treatability and heartwood natural durability

Species	Relative sapwood content	Sapwood treatability	Heartwood treatability	Heartwood durability
W. red cedar, yellow cypress,	Very low	Good	Poor	High
Northern white cedar	Moderate	Good	Poor	High
Red pine Ponderosa pine	High	Good	Poor	Low
White pine	Low	Good	Moderate	Moderate
Amabilis fir	Low/Moderate	Moderate	Moderate	Moderate
Western hemlock	Low/Moderate	Moderate	Moderate	Low/Moderate
Eastern hemlock	Low/Moderate	Moderate	Moderate	Low/Moderate
Douglas-fir – Coastal Second growth	Moderate	Moderate	Moderate	Moderate
Jack pine, Lodgepole pine	Moderate	Good	Poor/Moderate	Low/Moderate
W. Larch, Tamarack	Low	Moderate	Poor	Moderate
Alpine fir	Low/Moderate	Moderate/Good	Poor/Moderate	Low/Moderate
Balsam fir	Low/Moderate	Moderate	Poor/Moderate	Low/Moderate
White spruce, Engelmann spruce	Low	Poor	Poor/Moderate	Low/Moderate
Black spruce	Low	Poor	Very Poor	Low/Moderate
Douglas-fir Interior/Mountain	Low	Poor	Very Poor	Moderate



a **b**

Figure 3: Copper distribution in various species treated with CCA a) SPF; b) beech (top) and birch

Effect of preservative formulation on treatment of Canadian species

Effects of preservative type

Oil based preservatives such as creosote and penta-in-oil are applied to wood at high temperature and the combined effects of lower preservative viscosity, high temperature conditioning of the wood and the fact that these solutions are nonpolar results in better penetration than that obtained with typical water based systems such as CCA. Generally treating solutions that are amended with ammonia, penetrate better than pure amine and other ammonia-free formulations. (McFarling 2002, Morris et al. 2002). Furthermore formulations containing surfactants such as the quaternary ammonium components of ACQ generally have better penetration characteristics than CCA. This can be enhanced further by heating these solutions (Morris et al. 2006)

Interactions between preservative types and wood species

Different wood species respond differently to different preservative types as well. CCA does not penetrate Douglas-fir heartwood effectively due to the rapid reaction of the chemicals with the wood extractives. Ammoniacal and amine based preservative systems such as ACZA, ACQ and CA avoid this problem. Other species with high or specific extractive types also react quickly to reduce chromium in CCA solutions. This results in rapid chromium fixation, but poor arsenic fixation and high arsenic leaching in service. Species where this is evident include Douglas-fir, larch, maple, beech and oak (Cooper 2003).

These differences are less evident for treatment with oil-borne treatments, ammoniacal solutions and copper amine formulations, although there are still some differences in copper stabilization rates, for example with ACQ depending on the wood species (Ung and Cooper 2005).

2. Methods of treatment

Extending the pressure period with conventional processes does show some benefit in terms of increased penetration and retention in refractory species though there are diminishing returns after the first hour or two (Morris et al 1991a).

There have also been many attempts to enhance preservative treatment through the use of novel treating schedules and technologies, including oscillating or alternating pressure cycles, long pressure cycles and higher pressures. For example, Hösli and Ruddick (1988) showed that white spruce could be treated with CCA to meet ground contact retention requirements when pressure treated at high pressure (2.1 MPa or 310 psi) for long periods (20 hours) by either an empty cell process or an oscillating pressure process. Samples treated by a full cell treatment for 7 hours at 1 MPa pressure only met above ground retentions. The oscillating pressure treatment consisted of 60-80 oscillations between low pressure and 2.1 MPa and caused more damage to the wood than the conventional treatment.

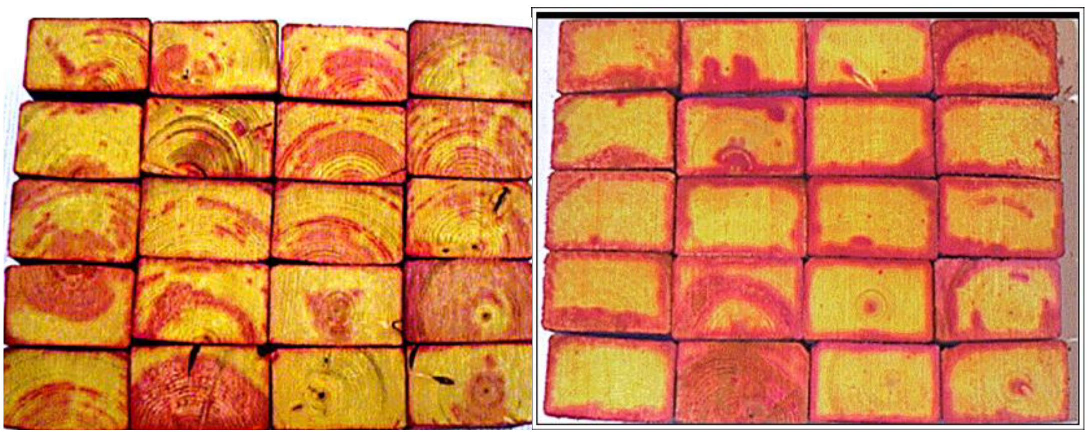
McFarling and Morris (2001) compared treatments with constant pressure of 1035 kPa with a conventional variable pressure method where the pressure is allowed to drop to 860 kPa as the solution is absorbed by the wood and a fluctuating pressure method (FPM) where the pressure cycles between 1000 and 1070 kPa. With unincised western hemlock, FPM provided the best treatment followed by constant pressure and variable pressure. In incised lumber, the effects were less significant and constant pressure was best followed by FPM and variable pressure. This suggests that moderate changes in the treating process can result in more consistent treatment of refractory species.

One approach to overcoming the thin sapwood and refractory heartwood limitations of many Canadian softwood species, such as species in the SPF and Hem-Fir species groupings is diffusion treatment with water soluble borates. By this process, the preservative can move in the moisture in the wood cell walls and lumens by molecular diffusion under a concentration gradient from the treated surface towards the untreated interior. This process is relatively slow, but spontaneous and will proceed on its own, after the preservative is loaded onto the wood surfaces by dipping in concentrated solutions or pressure treating with more dilute solutions. An example of borate distribution in black spruce immediately after treatment and after 1 week of storage for diffusion is shown in Figure 4.

It is essential that the surface be loaded with sufficient preservative to ensure an adequate penetration and retention in the assay zone following the diffusion phase. This can be accomplished, for example in kiln dried Canadian SPF, by heating the treating solution to 60°C to allow higher solution strengths and promote better penetration and pressing for 6 hours (Baker et al. 2001). Under these conditions SPF could be treated to levels required for protection against domestic termites and decay fungi, with a relatively short (1-2 weeks) diffusion period. Heating treating solutions was also shown to provide considerable benefit in green and dry hem-fir (McFarling 2002). Other factors that can improve the level of treatment are presteaming of the wood and incorporation of a surfactant in the treating solution (Morris 1996).

The advantages of this treatment are that the wood does not have to be dried (and in fact will treat better if in the green condition) and it is hardly dependent on the wood permeability and depends more on the wood density (low density is better) and moisture content (higher is better). The main limitation is that treated wood must be used in dry or protected applications because the borate is not fixed in wood.

Other approaches to overcoming poor treatability are to move from liquid phase to gas phase or supercritical fluid treatment but these are expensive in terms of capital equipment and seem to be difficult to apply in commercial operation. In gas phase treatment using trimethyl borate one of the biggest problems is removing the methanol, generated as a reaction product, from the wood. Slow pressure equilibration in supercritical fluid treatment of less permeable species can lead to pressure differentials causing collapse (Schneider et al. 2005)



(a) (b)

Figure 4: Borate penetration in black spruce a) immediately after treatment; b) after 1 week diffusion period without drying

Pretreatments: Drying, sterilization, incising, pre-compression

The treatment quality and performance of treated wood can be enhanced by pretreatments that improve the penetration of preservatives and reduce the susceptibility of wood to deterioration.

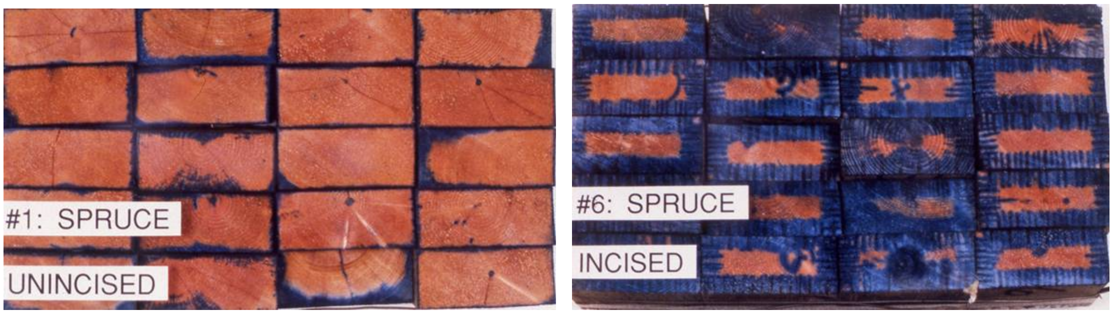
Large checks in round or boxed heart timbers can be a source of fungus spore penetration into untreated portions of the product though in smaller dimension material redistribution of copper onto untreated wood may prevent spore germination (Choi et al 2001). In larger dimension products, these radial splits can be partially controlled by putting a relief cut (kerf) along one surface to force the split on a specific face and to create an artificial check before treatment, which would be coated during treatment. Treated wood performance can also be promoted by eliminating fungi introduced into wood by disease in the growing tree or by pretreatment infection during storage or air drying. This can be accomplished by kiln drying at suitable temperatures or through steaming or other heat conditioning schedules to achieve a minimum wood core temperature of 56°C for 30 minutes or more. Finally, penetration can be optimized by ensuring that the wood moisture content is below fiber saturation point, to allow penetration into the cell lumens but that the wood is not so dry that permeability is reduced. It is generally recommended to dry to the 20-30% MC range (Morris 1991b).

Incising using an appropriate incising density and depth for the species and target standard is undoubtedly the most effective means of improving preservative penetration and retention (Morris et al 1994). The incising teeth not only separate wood fibres to allow deeper access of the preservative solution, but cut fibres to allow the preservative to move longitudinally from the incision (Morris et al 1991). For that reason, it is especially effective in species with high longitudinal permeability such as western hemlock. Incising round or sawn material will also, to some extent, reduce the development of large checks that penetrate below the treatment zone. This effect was demonstrated for decking made from a wide variety of Canadian species by Morris and Ingram (2002). Incising can be very effective for refractory species such as spruce (e.g., Figure 6a), but also for more treatable species such as red pine that has been over or under- dried before treatment (Figure 6b).

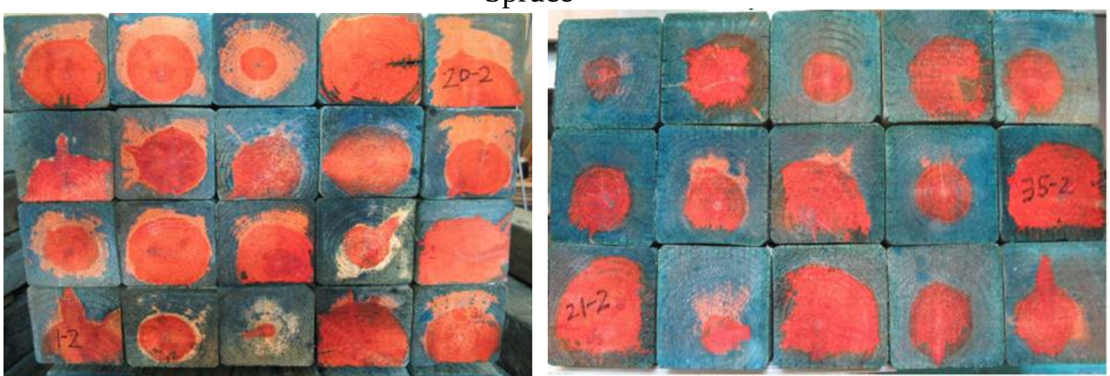
There have been a number of studies on the transverse compression treatment of wood to increase its drying rate and improve preservative penetration. Wood is typically dynamically compressed to 80-90% of its original thickness between two rollers at high speed. The wood rapidly recovers its full thickness, but it is likely that the stress results in some micro-checks and may even disrupt the bordered pits to allow better penetration. Cooper (1973) found that some enhanced penetration was possible, if boards were compressed in the radial direction (flat sawn boards), which indicates that the mechanism might be from stressing the bordered pits which are predominantly on the radial walls. For very refractory species such as interior Douglas-fir, the improvements are not practically significant.

Summary

Many Canadian species present challenges to treat consistently and the quality of treatment may be affected by the wood condition, treating system used and pretreatment and treatment conditions. By far the most significant factor is selection of the most permeable species of those available, however all strategies and approaches that can enhance penetration should be considered. These include proper pre-conditioning, incising and selection of the most appropriate treatment method and schedule.



Spruce



Un-incised - Full cell treatment, 1.0 pressure

Incised - Full cell treatment, 1.0 h pressure

Red pine

Figure 6: Effect of incising on treatment of refractory spruce (top) and more permeable red pine (bottom)

References

An, Y., Ruddick, J.N.R., Morris, P.I. 1998. CCA component distribution in the heartwood of treated lodgepole pine and white spruce. International Research Group on Wood Preservation, Document No. IRG/WP/98-30173. 10p

Baker, C., C. Wilson, S. McFarling and P. Morris. 2001. Pressure treatment of Canadian SPF with heated borate solutions. Proc. Cdn. Wood Preservation Assoc. . 22:69-78

Bramhall, G. and P.A. Cooper. 1972. Suitability of commercial Hem-fir for preservative-treated lumber and glued-laminated beams. For. Prod. J. 22(2): 33-37

Choi, S.M.; Ruddick, J.N.R.; Morris, P.I. 2001. The possible role of mobile CCA components in preventing spore germination in checked surfaces, in treated wood exposed above ground. International Research Group on Wood Preservation, Document No. IRG/WP/01-30263 16p

Cooper, P.A. and N.A. Ross. 1977. Treatability of Western hemlock lumber from coastal and interior B.C. regions with waterborne preservatives. For. Prod. J. 27(12): 36-39

Cooper, P.A. 1976. Pressure preservative treatment of poplar lumber. For. Prod. J.

26(7): 28-31

Cooper, P.A. 1973. Effects of species, precompression and seasoning on heartwood preservative treatability of six Western conifers. For. Prod. J. 23(7): 51-59

Cooper, P.A. 2003. Leaching of CCA – Facts and contradictions. 2003. Colley Hartford Lecture, Proceedings of the American Wood Preservation Association. 99: 73-97

Hösli, J.P. and J.N.R. Ruddick. 1988. Suitability of the pulsation process to pressure treat white spruce lumber with CCA. Forest Prod. J. 38(6):47-50

Lowe, J.J., K. Power, and S.L. Gray 1996. Canada's Forest Inventory 1991: the 1994 version An addendum to Canada's Forest Inventory 1991 Pacific Forestry Centre Information Report BC–X–362E

McFarling, S. 2002. Treatability of Canadian species with alternative preservatives. Proc. Cdn. Wood Preservation Assoc. 23: 147-155

Morrell, J.J. and P.I. Morris, 2002. Methods for improving preservative penetration into wood: a review. International Research Group on Wood Preservation, document No. IRG/WP/02-40227 17p

Morris, P.I. 1991a. Effect of treating schedule on double-density incised spruce-pine-fir. Forest Prod. J. 41(6):43-46

Morris, P.I. 1991b. Improved preservative treatment of spruce-pine-fir at higher moisture contents. Forest Prod. J. 41(11/12):29-32

Morris, P.I. 1995. Pacific silver fir is the more-treatable component of hem-fir from coastal British Columbia. Forest Prod. J. 45(9):37-40

Morris, P.I., Ingram, J.K. 2002. Field testing of wood preservatives in Canada. XI. Nine-year inspection of the CITW decking test. Proceedings Cdn Wood Preservation Assoc 22: 156-169

Morris, P.I., S.M. McFarling and A.R. Zahora. 2002. Treatability of refractory species with amine and amine/ammoniacal formulations of ACQ. Forest Prod. J. 52(10)37-42

Morris, P.I., J.J. Morrell, and J.N.R. Ruddick, 1994. A review of incising as a means of improving treatment of sawnwood. International Research Group on Wood Preservation, Document No. IRG/WP/94-40019. 24p

Morris, P.I., Ruddick, J.N.R., Silcox, R. 1991. Development, design and construction of a double-density incisor.. Forest Prod. J. 41(2):15-20

Schneider, P. F, J.J. Morrell and K.L. Levien. Internal pressuer development during supercritical fluid impregnation of wood. Wood and Fiber Sci. 37 (3): 413-423

Stevanovic-Janezic, T., P.A. Cooper and Y.T. Ung. 2001. Chromated copper arsenate treatment of North American hardwoods. Part 2. CCA leaching performance. Holzforschung. 55(1):7-12